

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

First named inventor: Gi Youl Kim Application No.: 10/791,334 Filed: March 1, 2004 Examiner: Turocy, David P. Art Unit: 1792 Docket No.: 40004551-0025-002 Confirmation No.: 2408 Customer No.: 26263	
--	--

DECLARATION OF STEVEN M. GEORGE

Steven M. George declares:

1. I am a Professor in the Departments of Chemistry (1991-present) and Chemical Engineering (2001-present) at the University of Colorado at Boulder. I hold a B.S. in chemistry from Yale University (1977) and a Ph.D. in chemistry from the University of California at Berkeley (1983) and was a Post-Doctoral Fellow at the California Institute of Technology (1983-1984). My research focuses on fabrication, design and properties of ultrathin films and nanostructures, and in particular the use of atomic layer deposition (ALD). I am currently directing an internationally recognized research effort focusing on ALD.

2. To date, I have authored more than 250 peer-reviewed publications in the areas of surface science, thin film growth and physical chemistry. I am a Fellow of the American Vacuum Society, the American Physical Society and the Alfred P. Sloan

Foundation. During my career, I have been recognized for my work through a number of awards including: the Presidential Young Investigator Award (1988-1993), American Chemical Society Colorado Section Award (2004), R&D 100 Award for Particle-ALD (2004), and Inventor of the Year, University of Colorado at Boulder (2004). I was the Chairman of the first AVS Topical Conference on Atomic Layer Deposition (ALD2001) held in Monterey, California. I have been a member of the Conference Committees for all subsequent ALD meetings, including, most recently, ALD2011 in Cambridge, Massachusetts. I am a member of the Editorial Board of Surface Review & Letters (1998-present) and was an Associate Editor for Chemical Reviews (1992-1994). I was Co-Chair of the Gordon Research Conference on "Chemistry of Electronic Materials" (1997) and was Chair of the Optical Society of America Topical Meeting on "Microphysics of Surfaces: Nanoscale Processing" (1995). I was a member of the Defense Science Study Group (1989-1991).

3. I understand that the real party in interest of the subject patent application (Application No.: 10/791,334) is Aixtron, Inc. of Sunnyvale, CA, and I confirm that I have no business affiliation with Aixtron, Inc. I have been compensated for my time in reviewing the file materials of the subject patent application and the preparation of this declaration.

4. I understand that claims 1, 15, 17, 18, 42, 43 and 47-50 of the subject patent application have been rejected under 35 USC 112, first paragraph, as not being enabling for chemistries other than TMA/H<sub>2</sub>O as further described in the Office Action mailed December 1, 2010. In preparing this declaration, I have read the subject patent application, including the presently pending claims, and the subject Office Action. I understand that the determination of whether or not a specification is enabling turns on the question of whether one of ordinary skill in the art would have to resort to undue experimentation in order to make and use the invention recited in the claims of the application.

5. I understand that claim 1 of the subject patent application, as currently amended, reads as follows:

An atomic layer deposition (ALD) process for using starved reactions, said ALD process comprising:

exposing a wafer to a starved dose of a first chemically reactive precursor, said starved dose being selected to yield less than one-half of a maximum saturated ALD growth rate, measured in film thickness per ALD process cycle, for said first chemically reactive precursor, wherein

said first chemically reactive precursor is a soft saturating precursor characterized by an onset of a slow increase in ALD growth rate with further increases of precursor exposure dose and having a longer saturation time as compared to a second chemically reactive precursor to follow the first chemically reactive precursor, and the exposure to the starved dose of the first chemically reactive precursor determines a value of a starved saturation ALD growth rate, measured in film thickness per ALD process cycle, for a second chemically reactive precursor to follow the first chemically reactive precursor, and

exposing the wafer to a dose of the second chemically reactive precursor, the dose of the second chemically reactive precursor selected for achieving starved saturation of the second chemically reactive precursor under variations of the second chemically reactive precursor, said

starved saturation characterized by an ALD growth rate, measured in film thickness per ALD cycle, of the second chemically reactive precursor being less than half of a maximum saturated ALD growth rate, measured in film thickness per ALD process cycle for the second precursor, wherein;

said starved dose of the first chemically reactive precursor and the dose of the second chemically reactive precursor are selected to obtain a maximum starved ALD process film deposition rate as measured in film thickness per unit time for the first and second chemically reactive precursors, and

said first and second chemically reactive precursors are delivered sequentially in time.

6. In the context of the subject patent application, one of ordinary skill in the art is, in my opinion, an engineer or scientist with experience in ALD technologies, including experience with experimental processes involving a variety of precursors. The individual may possess advanced degrees in chemistry, physics and/or engineering.

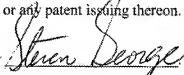
7. In the context of claim 1, one of ordinary skill in the art would not look to an infinite number of gases from which to select precursors for an ALD reaction. The fact that there are but a finite number of gasses suitable for such purposes is well known. It is also known that of these ALD-suitable gasses, there are fewer still that, when paired in an ALD reaction, have dissimilar reaction times. The present Specification provides several examples: combinations of TMA/H<sub>2</sub>O; TiCl<sub>4</sub>/NH<sub>3</sub>; various metal chlorides with H<sub>2</sub>O or NH<sub>3</sub>; non-metal bearing precursors containing an oxidant or a nitridant with a metal-bearing precursor; and HfO<sub>2</sub>, ZrO<sub>2</sub> and other oxides (La<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, Y<sub>2</sub>O<sub>3</sub>, and SiO<sub>2</sub>) using H<sub>2</sub>O and various nitrides (Si<sub>3</sub>N<sub>4</sub>, SiN, WN, TiN and TaN) using NH<sub>3</sub>. For a TMA/H<sub>2</sub>O chemistry, one of ordinary skill in the art would recognize that H<sub>2</sub>O is the precursor with the slower reacting half reaction and so would be the "first chemically active precursor" defined in claim 1. The same is true for any other established chemistry, such as TiCl<sub>4</sub> and NH<sub>3</sub>, used to deposit ALD TiN, where NH<sub>3</sub> is the precursor with the slower saturating reaction. With any other chemistries, only straightforward observations of the reaction rates would be needed to determine which was the "first chemically reactive precursor" for that chemistry. Thus, because the Specification mandates the use of gasses with non-similar reaction rates, those seeking to make and use the invention would recognize that the first and second precursors are limited to gasses from a defined set of ALD precursors.

8. In addition to the kinds of precursors, the Specification also addresses the issue of uniformity. In particular, it is stated that, "the precursors are delivered in a spatially distributed fashion substantially simultaneously to all points of interest on a substrate for a specified time interval." Specification at [0051]. It is known that when ALD doses which are less than those used to provide saturation (e.g., for the slower reacting reactant), then uniformity can be achieved by using a uniform injection of precursors into a reaction chamber, as is practiced in CVD, and described in the present Specification.

9. Thus, given the guidance provided in the Specification, one of ordinary skill in the art would not need to resort to undue experimentation to employ the claimed process with ALD precursors other than TMA/H<sub>2</sub>O that have non-similar reaction times. Once a pair of reaction chemistries is characterized for an ALD process showing saturation in both half reactions, there is high predictability and repeatability for the chemistry. The underlying mechanism for this is known from surface chemistry reactions. In the context of the presently claimed invention, the starved non-metal reactions take place at the surface, forming an assembly of non-saturated active -OH (hydroxyls) terminations to provide a fractional area coverage (set by  $t_s$  in contrast to conventional ALD, i.e., using  $t_0$  or  $t_{ex}$  of Fig 1A and 1B of the Specification). The sequential metal precursor (e.g., TiCl<sub>4</sub>) reactions chemically bond to those limited -OH active surface sites, resulting in the starved saturated level under metal precursor exposure; the metal precursor reactions leaves reactive terminating ligands (e.g., Al-CH<sub>3</sub> in the case of TMA, and Ti-Cl in the case of TiCl<sub>4</sub>) terminations for the next starved half cycle. This chemistry is highly predictable.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with such knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both (18 U.S.C. 1001) and may jeopardize the validity of the subject patent application or any patent issuing thereon.

Executed on February 26, 2011, at Boulder, Colorado, by

  
Steven M. George